A Survey on Various Fingerprint Image Enhancement Techniques

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Abstract- Fingerprints are the most widely used form of biometric identification. The performance of any fingerprint recognizer highly depends on the fingerprint image quality. Different types of noises in the fingerprint images affect the fingerprint recognition. However, fingerprint images are rarely of perfect quality. They may be degraded and corrupted due to variations in skin and impression conditions. Thus, image enhancement techniques are employed prior to minutiae extraction to obtain a more accurate estimation of minutiae locations. Image enhancement can be done using both spatial and frequency domain techniques. Most Automatic Fingerprint Identification Systems (AFIS) use some form of image enhancement. Therefore, this paper describes the comparison of various fingerprint image enhancement techniques.

Keywords: Image Enhancement; Spatial Domain; Frequency Domain.

1. INTRODUCTION

Nowadays the wide usage of biometric information for person identity verification purposes, and authentication process simplification in computer systems has raised significant attention to reliability and efficiency of biometric systems. Biometric mechanisms utilizes the measurements of a person’s behavioral characteristics (keyboard strokes, mouse movement) or biological characteristics (fingerprint, iris, nose, eyes, jaw, voice pattern, etc.). Fingerprint is one of the most prominent method among biometric techniques and has been used for individual authentication since 19th century. The two fundamental premises on which fingerprint recognition is based are: fingerprint details are permanent and fingerprints of individuals are unique. A fingerprint is formed of a group of curves. Historically, in law enforcement applications the acquisitions of fingerprint images was performed by using ink-technique. Now days they are captured as live-scan digital images acquired by directly sensing the fingerprint surface with an electronic fingerprint scanner. The fingerprint patterns exhibit different characteristics at different levels, the first type of level is global level of fingerprint analysis, it consider the ridges that flowing in various patterns, the two important ridge characteristics are ridge bifurcation and ridge termination. At this level fingerprint pattern exhibits one or more regions where ridge lines are characterized by high curvature. These regions are commonly used for assigning a fingerprint to a set of five distinctive classes (arch, tented arch, left loop, right loop, double loop and whorl).

A typical fingerprint-based recognition system works in two distinct modes, ie enrollment and recognition. Database creation is the purpose of the enrollment mode, this mode possess three sub stages: Fingerprint Reading, Image Preprocessing, and Feature Extraction. During the recognition mode, a fingerprint to be recognized undergoes the same three processing steps as in the enrollment mode and the result is compared with the feature from the database and a match
score is calculated. Higher values indicate higher confidence in recognition.

Need of Fingerprint Image Enhancement
The fingerprint recognition is an automated method for identifying the individual identity. The image enhancement step is needed to improve the image quality before the feature extraction. The commonly used approaches are filtering of the fingerprint images with filters adapted to local ridge orientation, and approaches based on direct ridge and Fourier domain processing are also exist. Fingerprint enhancement can be conducted on either binary ridge images or gray-scale images. Binarization before enhancement will generate more spurious minutiae structures and lose some valuable original fingerprint information; it also possess more difficulties for later enhancement procedure, so it is inherent limitations of this process. Different techniques for gray-level fingerprint images enhancement have been proposed assuming that the local ridge frequency and orientation can be reliably estimated. Pixel oriented enhancement schemes like Histogram Equalization, Mean and Variance normalization Weiner filtering [1] improve the legibility of the fingerprint but do not alter the ridge structure. L. O Gorman et al. proposed the use of contextual filters for fingerprint image enhancement. Hong and Jain have shown that ridges and valleys in a gray fingerprint image, forms a sinusoidal-shaped plane wave which possesses a clearly-defined frequency and orientation and used Gabor filter. Shen et al. applied Gabor filter to image sub-blocks and concluded that a good quality block can be identified by the outputs of Gabor filter bank. Greenberg proposed the use of an anisotropic filter that is based on structure adaptive filtering. Sherlock and Monro and Kamei and Mizoguchi perform contextual filtering completely in the Fourier Domain. The main reason for performing enhancement is to eradicate the noise in the fingerprint images, illuminate the parallel ridges and valleys and protect the true configuration of them. [2] The efficiency of fingerprint image enhancement algorithm is greatly depends on the quality of the fingerprint images. In order to obtain robust performance of a fingerprint image enhancement algorithm, that can improve the transparency of the ridge structures, is very essential.

Fingerprint Enhancement Methods
R.C. Gonzalez and R.E. Woods [3] have explained in his book that there is no general theory of image enhancement. When an image is processed for visual interpretation, the viewer is the ultimate judge of how well a particular methods works. Most of the quality checks have been used as a criterion, which determines image rejection, or a performance measurement of image enhancement algorithm. There have existed a variety of research activities along the stream of reducing noises and increasing the contrast between ridges and valleys in the gray-scale fingerprint images. Most popular among of them are spatial domain and other is frequency domain enhancement technique.

Spatial domain refers to the image plane itself, and image processing methods in this category are based on direct manipulation of pixels in an image. Spatial domain process discussed above can be denoted by the expression:

\[ g(x, y) = T[f(x, y)] \]

Where, \( f(x, y) \) is an input image, \( g(x, y) \) is an output image and \( T \) is an operator defined over the neighborhood of \((x, y)\). A 3 x 3 spatial mask

Frequency domain consists of modifying the Fourier transform of an image and then computing the inverse transform (Discrete Fourier Transform (DFT)) to get back to input image. Thus given a digital image \( f(x, y) \), of
size $M \times N$, the basic filtering equation in which we are interested has the form:

$$g(x, y) = \tau^{-1} [H(u, v) F(u, v)]$$

Where, $\tau^{-1}$ is the IDFT, $F(u, v)$ is the DFT of the input image $f(x, y)$, $H(u, v)$ is the filter function and $g(x, y)$ is the filtered output image. Specification of $H(u, v)$ is simplified considerably by using functions that are symmetric about the center. This is accomplished by multiplying the input image by $-1^{x+y}$ prior to computing its transform [3].

Comparison between spatial domain and frequency domain filtering: Using the filtering in the frequency domain enhancement task will become trivial to calculate. It causes computational efficiency for a large window size. Using the filtering in spatial domain we always specify a small spatial mask to capture the full filter function.

**COMPARITIVE STUDY**

L. Hong et al. [4] have explained an enhancement algorithm based on the minutiae extraction. It is one of the fastest fingerprint enhancement method, which can improve the clarity of ridges and valley of fingerprint images based on frequency domain filtering and ridge orientation. The improved goodness index and verification accuracy evaluates this method as an efficient one. Here the Gabor filter is applied to each pixels in the image.

S. Greenberg et al. [1] propose two methods for fingerprint image enhancement, the first method includes using local histogram equalization: Used to improve the contrast of the input fingerprint image, here the intensities are better distributed on histogram. This is mainly used to deal with either dark or bright backgrounds or foregrounds. Wiener filtering: Used to filter the noise from an input image and image binarization: Which is mostly performed as a part of image preprocessing. The second method performs the gray scale image enhancement. The result obtained is compared and a match score is obtained.

Zhang et al. [6] proposed an efficient fingerprint image enhancement algorithm using spatial-frequency filtering method. Here the filtering of the input image is done based on the predefined quality factor. For better filtering it incorporates the Gabor filter

since some parts of the images do not meet the quality factor requirement.

Yang et al. [7] in his work he has proposed a novel filter method for fingerprint image enhancement. Yang developed an enhanced version of the TGF (Traditional Gabor filter), called the modified Gabor filter (MGF) in order to overcome the drawbacks in their image selection strategy. The modification of the TGF made the MGF more accurate in preserving the fingerprint image topography. The remarkable advantages of the MGF over the TGF consist in preserving fingerprint image structure and image consistency. Experimental results indicate that the proposed MGF enhancement algorithm can reduce the FRR of a fingerprint matcher by approximately 2% at a FAR of 0.01%.

Kim et al. [5] proposed a novel enhancement algorithm for fingerprint image on the basis of image normalization and Gabor filter. Here the application of the adaptive normalization technique and the Gabor filter help in the significant improvement of enhancement experiments

Yun et al. [10] proposed an adaptive preprocessing method to improve image quality, the first phase involves the feature extraction for image quality analysis and then it involves the clustering module. Yun tested the proposed method on a private DB collected with careful consideration of image quality, and the results shows his proposed method is better than the existing ones, further he developed image characteristic factors for identification system.
Fronthaler et al. [11] proposed a method to enhance the fingerprint image quality, which improves the recognition performance. Here the input image is divided into three smaller images of different frequency bands and the contextual filtering is performed on the basis of these pyramid levels. Here all filtering is performed in the spatial domain. Fronthaler report on comparative results confirms that the suggested enhancement improves the feature detection, e.g. minutiae, which in turn improve the recognition.

Khan et al. [9] proposed directional filter to provide output in the form of directional images as opposed to directional sub-band provided in previous DFB. The method need the fingerprint image to be prepared before given to proposed DFB, since it is required for removing non-uniform illumination from the image. Final enhanced image result is constructed on a block-by-block on the energy basis of all the directional images and picking one that provides maximum energy.

Jun-tao et al. [13] proposed an image enhancement algorithm as a combination of both edge filter and Gabor filter. In edge filtering, the algorithm enhance the edges and segments the images into several blocks. Then a using multilevel block size method is used to extract the orientation field from the segmented image. Finally the Gabor filter is used to enhance the fingerprint image.

J.S. Bartunek et al. [18] proposed a new method for fingerprint image enhancement by using directional filters and binarization Directional filters are designed by frequency analysis in local area. The proposed algorithm was tested on numerous fingerprint images taken from the different databases. The proposed adaptive fingerprint binarization algorithm shows a good ability to tune itself to each fingerprint image.

Choudhary et al.[15] proposes a fingerprint enhancement method which can improve the ridge clarity and furrow structures of input image based on spatial and frequency domain filtering, local orientation estimation, local frequency estimation and morphological operations.

D. Bennet [26] develop a novel method for Fingerprint image enhancement method which is based on SVD and DWT. Here an automatic histogram threshold approach based on a fuzziness is measured. Here he compared medium and poor finger image features to get maximum recognition rate using fuzzy measures. The experimental results shows maximum performance.

Yang et al. [27] proposed a novel two-stage enhancement scheme in both the spatial domain and the frequency domain for low-quality fingerprint images. In his work he used a spatial ridge compensation filter in in the first stage enhancement to use the context information of the local ridge to connect or separate the ridges, the broken ridges will be connected and the merged ridges will be separated effectively based on this spatial filtering. In the second stage processing, the filter is separable in the radial and angular domains, respectively. Its parameters have adequately been determined by the information of both the original image and the enhanced image of the first stage instead of acquiring from the original image solely. The quality of the reconstructed images is determined by measuring the TMR and FMR of FVC2004 fingerprint database. The proposed fingerprint enhancement system using two stage filtering techniques gives high TMR and low FMR when compared to the Gabor filtering based fingerprint enhancement method and STFT enhancement.

I.G. Babatunde et al. [16] modified some of the sub models of an existing mathematical algorithm for the fingerprint image enhancement to obtain improved versions. The new versions consist of different mathematical
models for fingerprint image segmentation, normalization, ridge orientation estimation, ridge frequency estimation, Gabor filtering, binarization and thinning. The implementation was carried out in an environment characterized by Window Vista Home Basic operating system as platform and Matrix Laboratory (MatLab) as front end engine. The results show that the modified sub-models perform well with significant improvement over the original versions. The results also show the necessity of each level of the enhancement.

**Conclusion**

Survey of literature on fingerprint image enhancement put forward attention that there are more researches available in spatial domain filtering but very few research work found using filter in frequency domain. Though ridge orientation and ridge detection, on single pixel found very well in spatial domain filtering and also we can see very few work could be found taking ridge frequency enhancement in review literature process. There are few research work reviewed based on fuzzy logic concept and filter. From the review it is clear that fingerprint is of bad quality the feature extraction will become more difficult. Using of block processing instead of pixel processing help in reducing the computational complexities. The biometrics systems by coupled with bio hashing such that more security can be implemented for protecting privacy.

**VII References**

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